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Validation of ICDPIC software injury severity scores using a large regional trauma registry

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ABSTRACT

Background Administrative or quality improvement registries may or may not contain the elements needed for investigations by trauma researchers. International Classification of Diseases Program for Injury Categorisation (ICDPIC), a statistical program available through Stata, is a powerful tool that can extract ISSs from ICD-9-CM codes. We conducted a validation study for use of the ICDPIC in trauma research.

Methods We conducted a retrospective cohort validation study of 40 418 patients with injury using a large regional trauma registry. ICDPIC-generated ISSs for each body region were compared with trauma registry ISSs (gold standard) in adult and paediatric populations. A separate analysis was conducted among patients with traumatic brain injury (TBI) comparing the ICDPIC tool with ICD-9-CM embedded severity codes. Performance in characterising overall injury severity, by the ISS, was also assessed.

Results The ICDPIC tool generated substantial correlations in thoracic and abdominal trauma (weighted κ 0.87–0.92), and in head and neck trauma (weighted κ 0.76–0.83). The ICDPIC tool captured TBI severity better than ICD-9-CM code embedded severity and offered the advantage of generating a severity value for every patient (rather than having missing data). Its ability to produce an accurate ISS was consistent within each body region as well as overall.

Conclusions The ICDPIC tool performs well in classifying injury severity and is superior to ICD-9-CM embedded severity for TBI. Use of ICDPIC demonstrates substantial efficiency and may be a preferred tool in determining injury severity for large trauma datasets, provided researchers understand its limitations and take caution when examining smaller trauma datasets.

BACKGROUND

The Centers for Medicare & Medicaid Services (CMS) emphasises and incentivises the adoption of electronic medical records in healthcare allowing researchers to use the power of large medical datasets.[1] However, data can be stored in a variety of ways and in an inconsistent manner, which can make harvesting and interpreting administrative data for research purposes problematic. Researchers can face a difficult choice of working around potential limitations when analysing administrative datasets or using their limited resources to create datasets for research purposes at the expense of smaller sample sizes. International Classification of Diseases (ICD)-9 codes are usually embedded in large-scale administrative healthcare data giving researchers the ability to identify patients by clinical diagnoses.[2] These issues are especially important when assessing outcomes and quality of care.

Historically, the gold standards of injury severity have been the AIS[3] and the ISS (derived from the AIS). The AIS classifies injury into six distinct body regions (head and neck, face, thorax, abdomen, extremities and other) and is an ordinal value between 1 and 6 with an increase in score representing an exponential increase in severity (an abdominal injury severity of 4 is much more than twice as worse as a 2). The ISS uses the worst injury score in three separate body regions (the New ISS uses the three worst injuries, regardless of body region) to calculate a final score. AIS scores are only directly available from trauma registries which employ skilled personnel to review medical records, which can be both time-intensive and expensive.[4] Historically, the first software to produce AIS scores from ICD-9 codes was the ICDMAP,[5] first published in 1989 and made available at no cost; it has not been updated to be current with the latest versions of ICD-9 and AIS coding. More recently, a freeware statistical program implemented in Stata statistical software called ICD Program for Injury Categorisation (ICDPIC) has become available. While ICDPIC is free and readily accessible, it has been validated in only one study in the peer-reviewed literature.[6] However, this one study has a small sample size and is limited in its generalisability. Given the potential utility of this freeware tool and its frequent use in the recent medical literature,[7–16] we conducted a validation study in a large trauma population.

METHODS

Overview of study design

This retrospective medical record review was conducted to assess the validity of the ISSs generated by the publically available user-generated ICDPIC program[17] implemented in Stata statistical software (Statacorp LP, College Station, Texas, USA). AIS specific to body region and ISS derived by trained trauma nurses based on medical record reviews were considered the gold standards and were compared with AIS and ISS derived from the ICDPIC program. ICDPIC is designed to calculate AIS and ISS from ICD-9 diagnosis codes alone. For traumatic brain injury (TBI) specifically, two methods were compared with the gold standard method of generating head AIS: ICDPIC generated scores and those derived from the 5th digit of ICD-9 diagnosis codes.

Study samples and data source

The study sample included all trauma-registry-eligible admissions to Harborview Medical Center from April 2005 to August 2012. Paediatric

(<19 years) and adult (≥19 years) patients with trauma were studied separately. Harborview Medical Center in Seattle, Washington, is the only Level 1 trauma centre for four states (Alaska, Montana, Idaho and Washington) and provides the bulk of trauma care in this region. The Harborview Medical Center Trauma Registry houses data on all patients with trauma admitted or who die in the emergency department. Patients were excluded if their primary injury mechanism was classified as a 'burn', 'other' or was missing. Variables of interest in the trauma registry included age, AIS injury scores by body region as determined manually by a trained trauma nurse reviewer and ICD-9 codes. This study used strictly de-identified data and was, therefore, exempt from Institutional Review Board review.

AIS scores generated by the ICDPIC program were compared with gold standard assessments (manual chart review by trauma nurse) for five of six body regions (AIS Body Region 6 'External' was not examined as this region is not traditionally predicted by ICD-9-CM codes): head and neck, face, thorax, abdomen and extremities. While the ICDPIC program calculates AIS scores for body region 1 (combined Head and Neck), we evaluated the utility of the tool for classifying head injury alone by comparing this score with the actual head AIS generated by trauma nurse review. We also compared ICDPIC head and neck AIS values to those derived from the 5th digit of ICD-9 TBI diagnosis codes. The 5th digit from TBI ICD-9 codes (modified CDC definition of TBI using ICD-9 diagnosis codes—800.0–801.9, 800.00–801.99, 803.0–804.9, 803.00–804.99, 850.0–854.1, 850.00–854.19, excluded 950.1–950.3, 995.55 and 959.01) was used to assess TBI severity as the 5th digit corresponds to the length of loss of consciousness (LOC). The 5th digit codes were categorised in the following way: codes 1 (No LOC) and 2 (<1 h LOC) were classified as AIS scores of 1 and 2, respectively; codes 3 (1–24 h LOC), 4 (>24 h LOC with return to pre-existing conscious level) and 5 (>24 h LOC without return to pre-existing conscious level) were classified as AIS scores of 3, 4 and 5, respectively. Uninformative 5th digits (0, 6, and 9) could not be assigned to a severity score and were excluded from the analysis.

Statistical analysis

Agreement between ICDPIC-generated AIS scores and trauma registrar-generated AIS scores (and TBI ICD-9 5th digit based AIS scores for head injuries) was assessed using a κ statistic.[18] Additionally, a weighted κ was calculated for each body region giving exponentially less credit for increasing intervals of disagreement[18] (see online supplementary appendix for Matrices). Agreement between ISS values was determined by categorising ISSs into 10-point intervals (0–9, 10–19 and so on) and assessing the agreement using both a κ and weighted κ. We also reported the ability of the ICDPIC tool to identify serious injury (AIS ≥3) in each body region. Receiver-operating characteristic (ROC) curves were generated to examine the test performance characteristics of ICDPIC scores in classifying serious injury. Sensitivity and specificity were calculated for the two cut-off points that maximised the sum of sensitivity and specificity. In examining head injuries, ROC curves were generated for head AIS by each tool (ICDPIC for body region 1 and TBI ICD-9 5th Digit) to assess the relative performance of each tool in classifying serious TBI using the gold standard definition (AIS head injury score ≥3). This analysis was limited to a subset of patients with an informative 5th digit. The area under the curve (AUC) for the two methods were compared statistically using a χ^2 statistic.

Table 1 Characteristics of trauma admissions at Harborview Medical Center April 2005–August 2012

Characteristic	Adults	Children
Number of patients	33 322	7096
Age (SD)	47.2 (19.5)	11.8 (6.3)
Trauma type (%)		
Penetrating	12.8	14.1
Blunt	87.2	85.9
Length of stay in days (SD)	6.8 (10.8)	4.0 (7.4)
Survived hospitalisation (%)	95	98
ISS—Median (IQR)	11 (6–21)	10 (5–18)

All test performance characteristics were studied separately for adult and paediatric patients with trauma. All analyses were conducted in Stata Intercooled V.12 (Statacorp LP).

RESULTS

Patient characteristics

There were 33 322 adult and 7096 paediatric patients in this cohort (table 1). In general, patients had blunt mechanism of injury (87% adult, 86% paediatric), length of stay of 7 days for adults, 4 days for children, survived hospitalisation (95% of adults, 98% of children) and had serious injury (median ISSs of 11 in adults, 10 in children).

Agreement between ICDPIC AIS and Trauma Nurse AIS scores

On average, agreement between the ICDPIC AIS scores and Trauma Nurse AIS scores was slightly better in the adult cohort than in the paediatric cohort (table 2). Agreement differed by body region as measured by κ (0.36–0.72) and weighted κ (0.69–0.92) values. Agreement was substantial for thoracic and abdominal injuries when using standard κ values and almost perfect when using weighted κ values, moderate for head/neck and extremity injuries when using a standard κ value and substantial when using weighted κ values, fair for face injuries when using a standard κ and substantial when using weighted κ values, while it was moderate for extremities for standard κ and substantial using weighted κ values (table 2).

Classifying serious injury by body region using ICDPIC scores

The ICDPIC tool tended to do very well in separating serious injury from more mild injury for all body regions observed (AUC 0.864–0.980) compared with the gold standard of trauma

Table 2 κ and weighted κ statistics for the comparison of International Classification of Diseases Program for Injury Categorisation (ICDPIC) body region-specific AIS and ISS to gold standard

	Adults		Children	
	κ	Weighted κ	κ	Weighted κ
Head and neck	0.57	0.83	0.51	0.76
Face	0.39	0.73	0.36	0.69
Thorax	0.68	0.91	0.60	0.87
Abdomen	0.72	0.92	0.68	0.92
Extremities	0.44	0.75	0.45	0.77
ISS*	0.38	0.73	0.40	0.70

*ISS agreement assessed in 10-point ordinal intervals.

Table 3 Area under receiver-operating characteristic curves (AUC) to classify serious injury (AIS ≥3) using International Classification of Diseases Program for Injury Categorisation (ICDPIC)

			ICDPIC ≥2		ICDPIC ≥3	
	AUC	95% CI	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Adults						
Head and neck	0.902	(0.898 to 0.906)	86.6	75.9	73.2	97.7
Face	0.953	(0.949 to 0.957)	97.4	92.7	6.8	99.9
Thorax	0.958	(0.954 to 0.961)	90.1	95.0	73.9	99.6
Abdomen	0.969	(0.966 to 0.971)	97.0	92.0	54.7	99.5
Extremities	0.891	(0.887 to 0.895)	87.0	83.6	44.6	99.5
ISS (≥16)	0.892	(0.888 to 0.896)			ICDPIC ISS ≥16	
					79.9	88.4
ISS (≥25)	0.896	(0.891 to 0.901)			ICDPIC ISS ≥25	
					75.1	91.2
Children						
Head and neck	0.864	(0.853 to 0.874)	81.4	71.0	69.6	98.1
Face	0.952	(0.943 to 0.961)	97.4	91.9	8.7	99.9
Thorax	0.927	(0.916 to 0.938)	83.3	97.7	76.1	99.6
Abdomen	0.980	(0.976 to 0.984)	97.7	94.1	61.5	99.7
Extremities	0.921	(0.912 to 0.930)	86.8	93.4	52.0	99.7
ISS (≥16)	0.888	(0.878 to 0.897)			ICDPIC ISS ≥16	
					78.0	90.0
ISS (≥25)	0.902	(0.892 to 0.913)			ICDPIC ISS ≥25	
					71.4	92.3

nurse assessment. Using an ICDPIC-generated AIS cut-off score of 3 to identify AIS ≥3 injuries was highly specific for all body regions (98.1%–99.9%), but demonstrated relatively low sensitivity (6.8%–76.1%). In contrast, using an ICDPIC-generated AIS score of 2 to identify trauma nurse scored AIS ≥3 injuries improved sensitivity estimates substantially, but at some cost to specificity (table 3).

The ICDPIC-derived ISS classifying major trauma (ISS ≥16) was specific (88.4% and 90.0%, respectively) and sensitive (79.9% and 78.0%, respectively) in both adults and children. For more severe trauma (ISS ≥25), it performed similarly.

Classifying serious head injury with ICDPIC AIS scores and TBI ICD-9 5th digit numbers

The area under the ROC curves using ICDPIC and ICD-9 5th digit generated AIS scores to classify serious head injury using the trauma nurse score of AIS ≥3 as a gold standard was consistently high (table 4). The ROC curve of ICDPIC's performance in classifying serious TBI resulted in an AUC of 0.902 for adults (figure 1) and 0.864 for children (figure 2). The ICDPIC AIS cut-off of ≥3 demonstrated sensitivity and specificity estimates of 79.3% and 94.9%, respectively, in the classification of serious TBI. Sensitivity was only slightly improved at a larger decrease in specificity when using a score of 2 or greater.

Limiting to patients with informative TBI ICD-9 5th digit (66% of sample), the ICDPIC ROC curve demonstrated an AUC of 0.971 for adults and 0.973 for children. The corresponding ROC curve using the ICD-9 5th digit approach was 0.921 for adults and 0.905 for children. The ICDPIC tool demonstrated a sensitivity of 95.2% and specificity of 94.9% using a cut-off score of 3 while the ICD-9 5th digit tool demonstrated a sensitivity of 90.4% and a specificity of 96.7%. Both tools gained sensitivity and lost specificity when a score of 2 was used as a cut-off. The ICDPIC approach significantly out-performed the ICD-9 5th digit approach in comparing AUC (difference in AUC of 0.0502 for adults and 0.0687 for children, both $p<0.001$).

Table 4 Area under receiver-operating curves to classify serious head injury (AIS ≥3)

			Score ≥2		Score ≥3	
	AUC	95% CI	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Adults						
ICDPIC	0.882	(0.878 to 0.887)	84.8	71.0	79.3	94.9
ICDPIC*	0.971	(0.970 to 0.973)	99.7	76.6	95.2	94.9
ICD-9 5th digit*	0.921	(0.918 to 0.924)	88.8	83.6	20.5	99.97
Children						
ICDPIC	0.858	(0.847 to 0.869)	81.0	69.1	72.1	96.9
ICDPIC*	0.973	(0.970 to 0.977)	99.9	77.1	90.4	96.7
ICD-9 5th digit*	0.905	(0.898 to 0.911)	85.4	80.5	20.3	100.0

*Includes only informative ICD-9 5th Digit Patients, 67.6% of adults and 60.6% of children had informative 5th digits.
ICDPIC, International Classification of Diseases Program for Injury Categorisation.

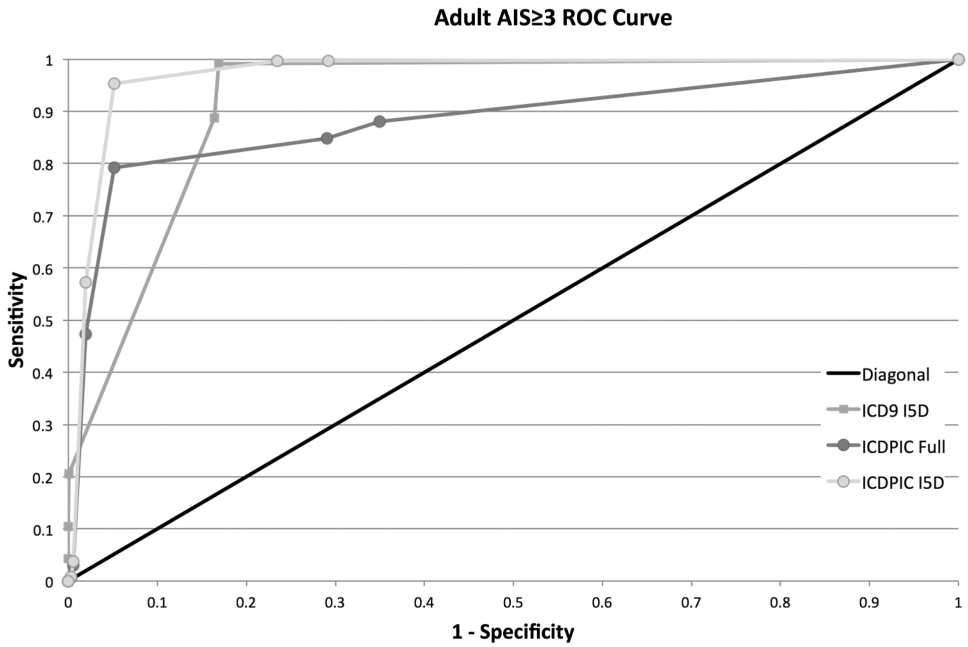

Figure 1 Adult receiver-operating curve using International Classification of Diseases Program for Injury Categorisation (ICDPIC) (in all patients and patients with only an informative 5th digit) and ICD-9 5th digit severity (I5D) to predict serious traumatic brain injury (head AIS ≥3).

DISCUSSION

The ICDPIC tool classified injury severity by body region reasonably well for thoracic and abdominal injuries, moderately well for head and neck injuries, but only fairly for face and extremity injuries. It performed quite well in classifying serious injury (AIS ≥3) for each body region, specifically for TBI. The ICDPIC demonstrated superior predictive power in capturing serious TBI to using ICD-9 5th digits alone and offers other advantages to the use of ICD-9 5th digits. Using ICDPIC allows use of the entire sample rather than the subset of patients with informative 5th digits. While missing data techniques such as multiple imputation could be used with the 5th digit technique, the missing data mechanism would be unclear and would be subject to bias unless the data was missing-at-random. In general, both tools offered highly specific approaches at the cost of sensitivity.

The results of our study outline how one might use these tools in research. If a researcher's aim is to use ICDPIC to generate a measure of injury severity by body region, this study supports doing so for thoracic and abdominal injuries, moderately supports it for head and neck injuries, and supports doing so for face or extremity with less enthusiasm. If a researcher's aim is to minimise false-positives in a particular dataset for serious injuries, the ICDPIC tool performs well in exhibiting specificities greater than 98% for each body region and for overall injury. Similarly, the ICDPIC tool can help minimise false-

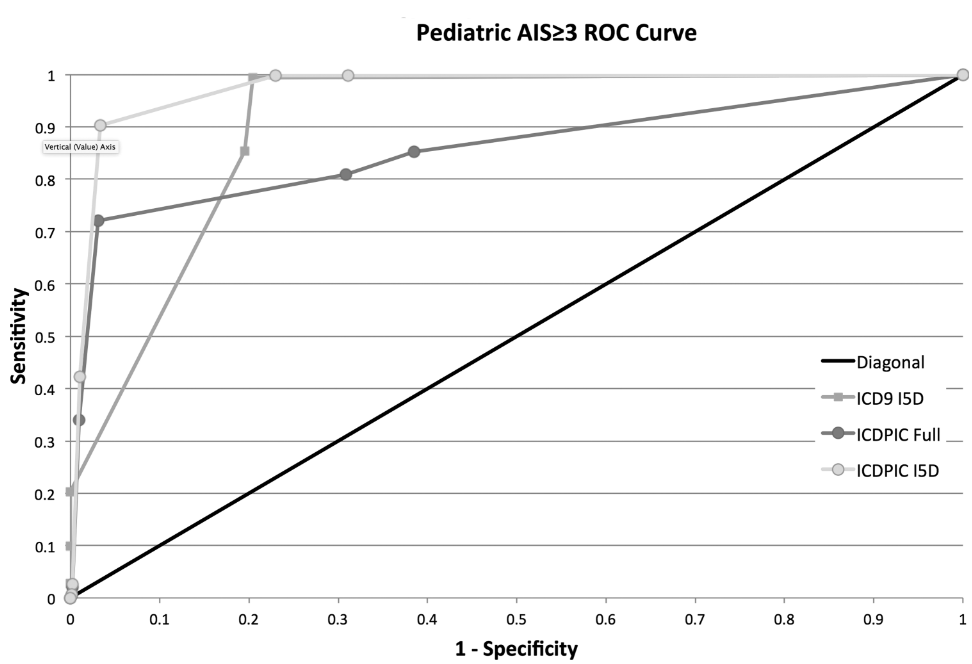

Figure 2 Paediatric receiver-operating curve using International Classification of Diseases Program for Injury Categorisation (ICDPIC) (in all patients and patients with only an informative 5th digit) and ICD-9 5th digit severity (I5D) to predict serious traumatic brain injury (head AIS ≥3).

negatives by using a lower score to ‘catch’ all AIS ≥3 injuries without sacrificing much specificity. Researchers with a need to identify serious TBI can use the ICDPIC tool with confidence, but less enthusiastically use ICD-9 5th digit technique as it can be assumed that there might be an inherent problem with the mechanism of missingness. More minor injuries might be ‘unspecified’ more often, which gives reason to believe that the probability of missingness may depend on the actual severity of injury, which would by definition make the missing data mechanism not missing-at-random. However, this may not be true in all datasets. The mechanism of missingness may vary depending on how data was collected. Depending on the analytic strategy, the need for high specificity and the ratio of informative to uninformative 5th digits, a researcher can use either tool to accurately identify serious injury.

The limitations of this validation study should be considered when interpreting our results. The population studied is that of Harborview Medical Center, where all patients with severe trauma within a four state area (Alaska, Montana, Idaho and Washington) are treated. A majority of the patients with trauma in this study had blunt mechanisms of injury (87%) and therefore, our results may not be as generalisable to populations with a majority of penetrating mechanisms. Because this data is also from one system, there may be particular behaviours or practices by trauma registry nurses that limit the generalisability of our results.

The most important conclusion injury researchers should take away is that preliminary evidence from this study suggests that the ICDPIC tool can be used effectively to identify types of injury and severity of injury present in datasets containing ICD-9 based codes. As ICD-10 will become the standard, the ICDPIC algorithm will need to be updated, and another validation study will need to be performed. Until ICD-10 is widely adopted and in use, this ICDPIC software will continue to demonstrate that its use as a retrospective review of any dataset prior to the adoption of ICD-10 will require this type of software. We also note that the ICDPIC tool performs extremely well in the subset of the population defined by presence of an informative 5th digit. This fact underscores the importance for institutions to code with as much detail as possible. While codes without a 5th digit can be used, they are not as informative when performing retrospective research. It is our hope that ICD-10 will help solve this problem by providing further granularity with its coding and that institutions will attempt to code with the highest level of granularity available.

While ICDPIC may not offer superiority over severity variables in trauma registry datasets, its utility in generating injury severity measures may prove very useful when analysing larger administrative datasets, depending on the research question and provided the researcher takes into account the limitations identified in this study.

What is already known on this subject

- International Classification of Diseases Program for Injury Categorisation (ICDPIC), a freeware statistical program implemented in Stata statistical software, is being more commonly used in injury and trauma research.
- Only one small-scale study in the literature exists to date to attempt to validate this tool.

What this study adds

- This is a large-scale validation study that attempts to validate the ICDPIC tool and demonstrates its strengths and weaknesses when applied to large datasets.
- Offers comparison with using ICD-9 code embedded severity to estimate severity of head injury in particular.

Contributors NG made substantial contributions to concept and design, acquisition of data, analysis and interpretation of data, drafting and revising the article critically for important intellectual content, and final approval of the version to be published. Nathaniel is the guarantor for overall content for publication. MK made substantial contributions to concept and design, analysis and interpretation of data, revising the article critically for important intellectual content, and final approval of the version to be published. MV made substantial contribution to analysis and interpretation of the data, revising the article critically for important intellectual content, and final approval of the version to be published. FR made substantial contribution to concept and design, acquisition of data, analysis and interpretation of data, revising the article critically for important intellectual content, and final approval of the version to be published.

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Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement We used data available to the public through the Healthcare Cost and Utilisation Project via the Agency for Healthcare Research and Quality of the USA. We also used data from our own trauma registry. Both of these datasets will not be openly shared by the investigators.

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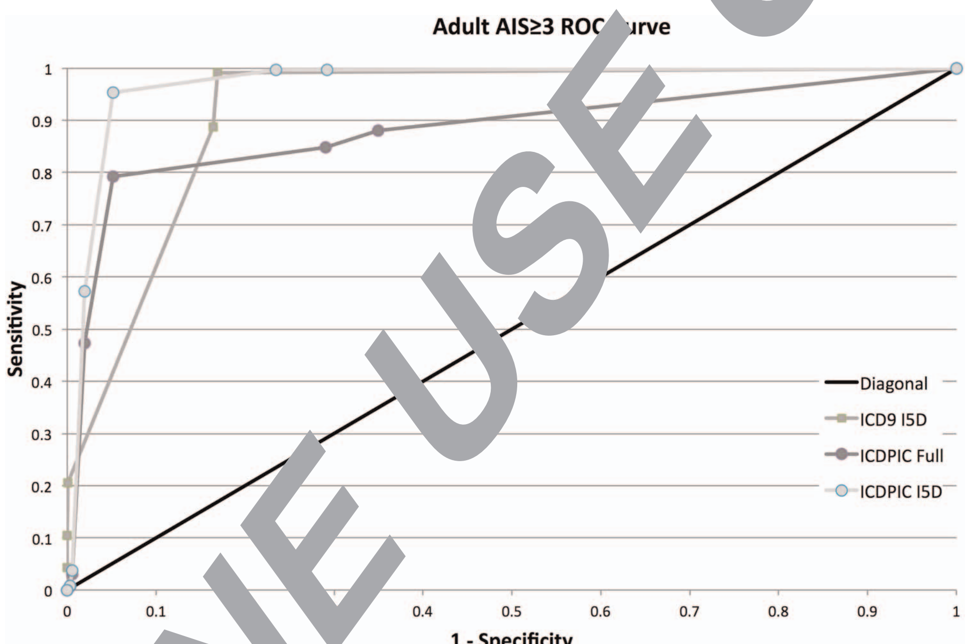
Adult AIS≥3 ROC Curve
Sensitivity
1 - Specificity
0
0.1
0.2
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ICD9 I5D
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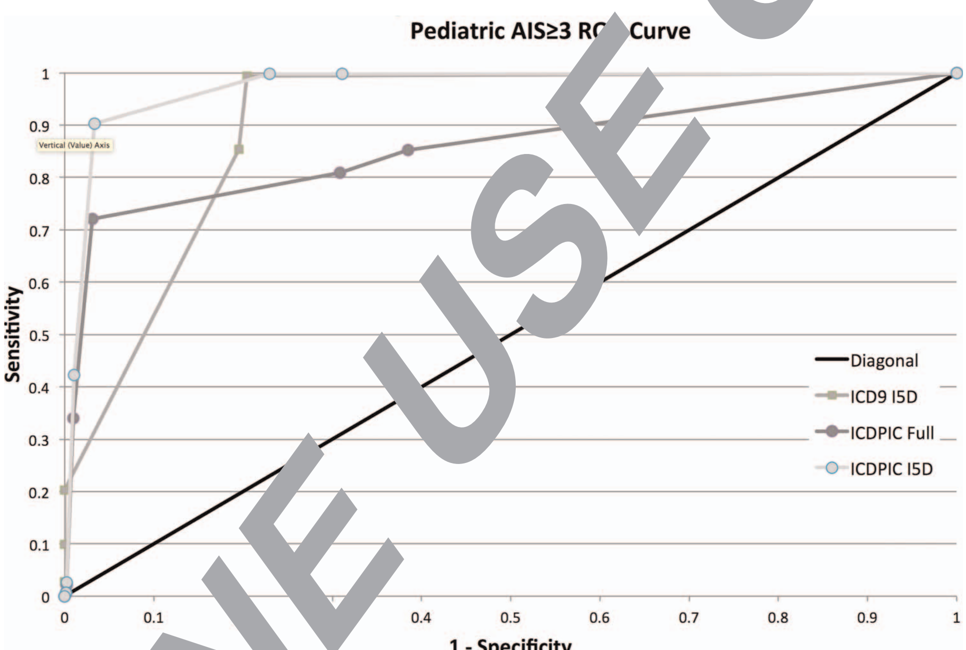
Pediatric AIS≥3
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